RESEARCH SUPPORTING SOUND DECISIONS

JOINT FIRE SCIENCE PROGRAM

2019 PROGRESS REPORT

Program Vision Statement:
The Joint Fire Science Program provides funding and science delivery for scientific studies associated with managing wildland fire, fuel, and fire-impacted ecosystems to respond to emerging needs of managers, practitioners, and policymakers from local to national levels.

Overview of the Joint Fire Science Program

"No other program has a service-wide view of fire research, and no other program delivers science across the spectrum of users in the fire and land management community like JFSP."

–John Laurence, former JFSP Governing Board member

Congress created the Joint Fire Science Program (JFSP) in 1998 as a partnership between the U.S. Department of Agriculture Forest Service and the Department of the Interior to identify and fund the research needs of the fire management community. Since that time, the JFSP has provided leadership to the fire community by identifying high-priority wildland fire science research needs that will enhance the decisionmaking ability of fire and fuels managers, natural resource managers, and others to meet their management objectives. This progress report highlights a small sample of those research projects. The program also meets the decision needs of those involved in developing and implementing fire-related policy. The program's breadth of stakeholders has broadened over the years commensurate with its science mandate; however, the JFSP remains focused on actionable science and tangible outcomes that meet the needs of end users.

A Unique Role in the Fire Science Community

The JFSP responds to the emerging needs of stakeholders by tailoring timely wildland fire research through an annual cycle of proposal solicitation, review, funding, and science delivery. JFSP research projects complement and extend the in-house capacity of other federal fire research programs, including the U.S. Forest Service research stations and the U.S. Geological Survey. What really sets the JFSP apart from its partners and other fire research funding entities is its emphasis on science to support management.

Real Progress Through Science

This progress report highlights some of the many contributions and impacts of the JFSP over the past 2 years including:

- Continued scientific output from wildland fire research through manuscripts, management briefs, decision-support tools, and syntheses.
- Efficient delivery of wildland fire science to practitioners through the nationwide Fire Science Exchange Network.
- Incorporation of wildland fire science to improve policy, restoration success, public and firefighter health and safety, and fuels management, among others.

Twenty Years of the Joint Fire Science Program—
A Retrospective

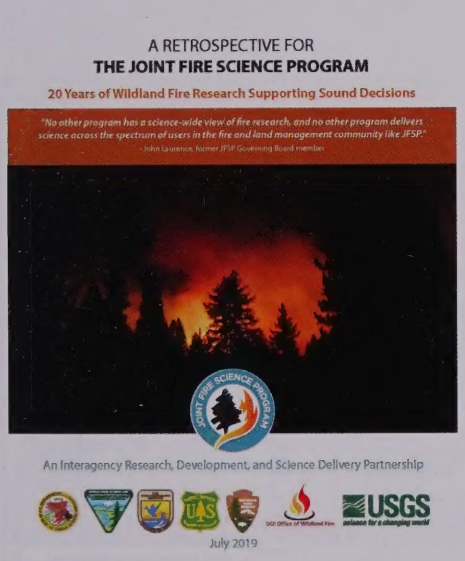
History and Evolution of the Program

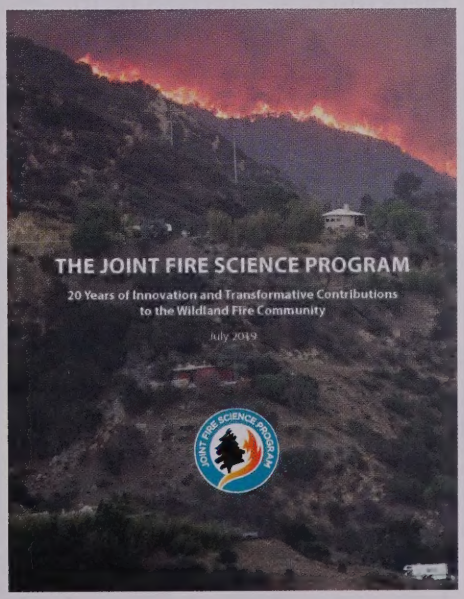
Following its twentieth year of service, the JFSP released a retrospective report and summary companion document. The retrospective highlights key scientific advances, enhanced management outcomes, and lessons learned over the past 2 decades achieved through JFSP-funded fire science research. In addition, it illuminates how the adoption and application of fire science has matured because of the JFSP's deliberate efforts toward science delivery including the Fire Science Exchange Network.

"Without the JFSP, there would only be baby steps in fire science."

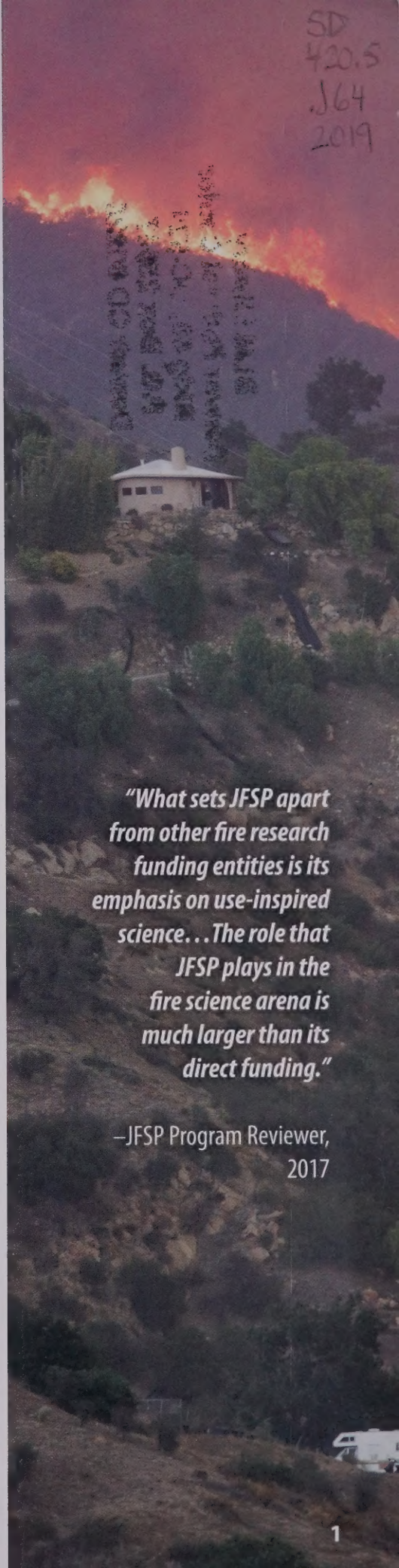
–Pete Robichaud, research engineer

The JFSP has distinguished itself as a highly efficient mechanism to connect wildland fire science research to effective management of fire and fire-prone landscapes. Through regular reflection and review of its mission, vision, and growth, the JFSP is a successful model for tackling complex fire management questions and delivering knowledge and tools to land managers. Through use of an open and competitive research process, the JFSP has expanded the wildland fire science field by encouraging collaborative research among more than 300 federal, university, state, tribal, industry, and nonprofit organizations. Promoting cooperative research not only spurs innovation and broader engagement within the fire science communities, it also results in substantial leveraging of funds and expertise to address the critical wildland fire science and management issues of our time. To explore results of the JFSP's efforts, go to: https://www.firescience.gov/JFSP_publications.cfm.





JFSP 20-year retrospective and summary companion document published to highlight the JFSP's efforts since its origin. Both documents are available at: https://www.firescience.gov/JFSP_publications.cfm.



Social Science Spotlight:

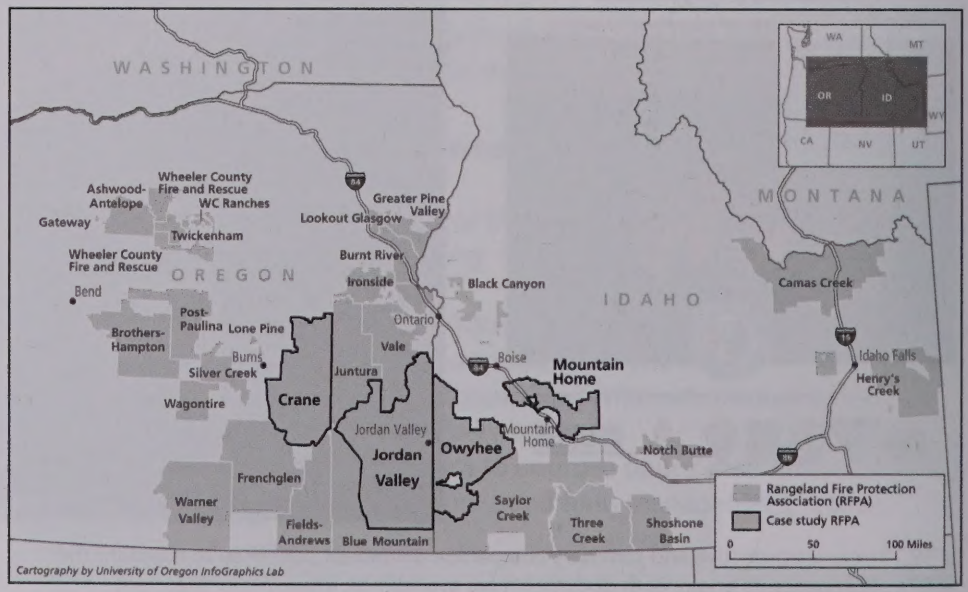
Rangeland Fire Protection Associations

E.J. Davis, Oregon State University

The size and frequency of fires in the Great Basin are greater now than at any time in the recent past. These fires are fueled by invasive grasses and exacerbated by the remoteness of the areas in which they occur. Federal fire suppression resources are generally centered around larger communities, and thus, response to remote locations may be delayed. One potential partnership that can help address wildfire issues in this region is the Rangeland Fire Protection Associations (RFPAs).

RFPAs are volunteer groups of landowners, often ranchers, trained and authorized to respond to wildfires. They have been operational in Oregon for decades and are now active in Idaho and Nevada, too. Historically, liability and safety concerns have been associated with rancher involvement in fire suppression response on public lands managed by the Bureau of Land Management (BLM). JFSP-funded research by Emily Jane Davis, an assistant professor at Oregon State University, examined four RFPAs to determine how the federal land management agencies, such as the BLM, can better work with RFPAs.

RFPAs function through state statutes with minimum standards for training and protection from liability as registered nonprofits. They have delegated authority from the state to respond to wildfire on state and private lands but must have a separate agreement to operate on federal lands. There are several advantages of RFPAs. The members of RFPAs have a vested interest in quickly suppressing fires to protect their and their neighbors' homes and rangelands. Additionally, they live and work near where fires start and have the best knowledge of the local area including the road network and water sources. "The RPFA model harnesses the advantages of ranchers: local knowledge, quick response, and passion for where they live and work," said Davis.



Map of locations of Rangeland Fire Protection Associations in Oregon and Idaho.

Some of the major findings of the research (Davis et al. 2019) include:

1. Relationships between RFPA members and federal fire management personnel improved when there was an investment spent in planning and training together. RFPA members acquired better tactical understanding of suppression operation and gained better understanding for the justification of federal fire management policy. As a result, joint operations became more efficient and trust between parties improved.

2. Participation and cooperation on joint suppression operation can lead to interest in other wildfire management activities such as hazardous fuels management. In some cases, this has led to more effective, coordinated fuel breaks across federal and private lands.

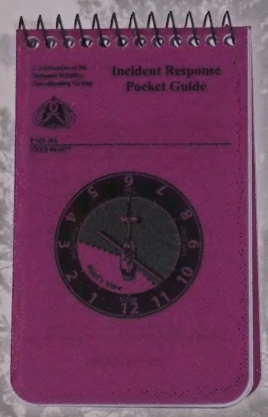
As of 2019, RFPAs were assisting in fire suppression efforts across more than 25 million acres in Idaho, Nevada, and Oregon, and new RFPAs continue to be formed. Part of this expansion is due to improved relationships between the RFPAs and federal agencies. "Working side by side during a wildfire forces ranchers and firefighters to find common ground pretty fast," according to Davis. The value of these improved relationships has already proved beneficial. For example, during the busy 2018 wildfire season when approximately 8.8 million acres burned nationally, RFPAs responded to 168 wildfire incidents in Oregon alone. At times, the 2018 season was so busy that resources were not available unless they were taken from another incident; the RFPAs provided much needed relief. This research demonstrates the importance of developing partnerships with local firefighting resources and provides a model for its success.

Oregon Department of Forestry

Members of an Oregon Rangeland Fire Protection Association assist with a wildfire incident.

Darren McAvoy, Utah State University

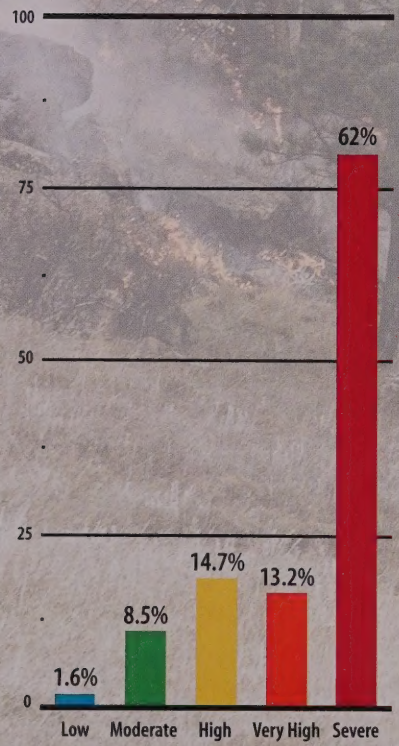
Emily Jane Davis, Oregon State University assistant professor.



Kelsey Brizendine

Firefighters practice shelter deployment as part of their annual training.

Figure 1. Number of entrapment fatalities (y-axis) and the associated Severe Fire Danger Index categories from 1979 to 2017. Derived from Jolly et al. 2019.



Research Emphasizes

Firefighter Safety

For every fire, the number one management priority is always firefighter and public safety. Two important studies, funded through the JFSP, focused specifically on recognizing conditions related to fire entrapment fatalities and estimating the appropriate safety zone size to prevent injuries.

The Severe Fire Danger Index

The first study by Matt Jolly and others at the Missoula Fire Sciences Lab developed a nationwide index called the Severe Fire Danger Index (SFDI) related to fire intensity and spread potential that can be used to assess risk (Jolly et al. 2019). This index has five categories: low, moderate, high, very high, and severe. The SFDI was shown to be a strong predictor of burnover fatalities, or fatalities that occur where fire overtakes personnel and there is no opportunity to utilize escape routes and safety zones. In fact, more than 75% of fatalities (from 1979 to 2017) occurred when the index was "very high" or "severe" (Figure 1). Because the index can be predicted ahead of time, it can be used by fire managers and communities to modify tactics, assess the need for evacuations, and reduce risk to protect human life.

Safety Zone Research Becomes New Guideline

The second study, by Wesley Page and Bret Butler, also at the Missoula Fire Sciences Lab, evaluated the guidelines for determining the size of safety zones, or locations where a threatened firefighter can find adequate refuge from an approaching fire. They found that under most conditions, the recommended safety zone sizes were inadequate. Indeed, the previous guidelines for safety zones only considered fire on flat terrain and with no wind; very few fires occur under that scenario. The new guidelines they developed adjust the safety zone size using a slope-wind factor. The greater the slope and/or the greater the wind, the larger the safety zone needs to be to provide a safe separation distance (Figure 2). The guidelines were immediately incorporated into the latest version of the Incident Response Pocket Guide, which provides information for firefighters on best practices for all aspects of incident response. Firefighters now have better information

Figure 2. New safety zone guidelines incorporate wind speed, terrain slope, and fuel height.

Slope-Wind Factor (Δ)

	Terrain Slope (%)		
Wind Speed (mph)	Flat (<15%)	15-30%	>35%
Light (0-6)	1 / 0.7 / 0.7	1 / 1 / 1	4 / 2 / 2
Moderate (7-15)	2 / 1 / 1	4 / 2 / 1	6 / 3 / 2
Strong (>18)	4 / 2 / 2	6 / 3 / 2	8 / 3 / 2

Fuels < 10' tall / 10' < Fuel < 40' / Fuel > 40'

Other Firefighter Safety Research Funded in 2018 and 2019 through JFSP

The following is additional firefighter safety research that can be used by incident commanders and firefighters.

Page, W.G., and B.W. Butler. 2018. Fuel and topographic influence on wildland firefighter burnover fatalities in Southern California. International Journal of Wildland Fire 27: 141-154.

Using past fatal firefighter burnover locations in Southen California, researchers identified and characterized the environmental variables (e.g., slope, aspect, fuel type), which commonly produce the dangerous conditions associated with these tragic events. By understanding the danger associated with certain locations on a fire, incident commanders may adjust strategies and tactics to avoid putting firefighters at greater risk.

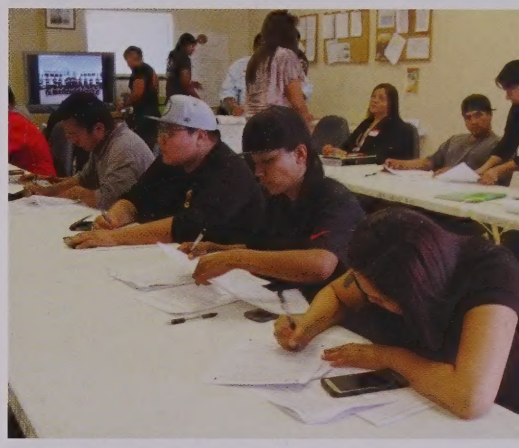
Page, W.G., P.H. Freeborn, B.W. Butler, and W.M. Jolly. 2019. A review of US wildland firefighter entrapments: Trends, important environmental factors and research needs. International Journal of Wildland Fire 28: 551-569.

Entrapments are most common when fire behavior significantly deviates from predicted models and firefighter ecape routes or saftety zones are compromised. This review explores a new method to evaluate entrapment data that can be used to specify the relative influence of environmental variables on entrapment probability.

Page, W.G., P.H. Freeborn, B.W. Butler, and W.M. Jolly. 2019. A classification of US wildland firefighter entrapments based on coincident fuels, weather, and topography. Fire 2: 52.

Researchers analyzed entrapment events involving more than 1,200 firefighters from 1981 to 2017 with respect to a host of environmental variables, many of which are part of standard firefighter training for common denominators of fire behavior on tragedy fires. This research concluded: (1) fire conditions do not need to be extreme for an entrapment to occur, just unexpected; (2) the environmental conditions which lead to entrapments in one region do not necessarily carry over to another region; and (3) human behavior is a critical yet unpredictable factor.

Kari Greer



"Firefighters should understand the risks associated with smoke exposure and be educated on practices to reduce exposure."

–Joe Domitrovich, MD, U.S. Forest Service researcher

Smoke Impacts on Firefighter and Public Health

Although funding opportunities through the JFSP Smoke Science Plan ended in 2016, past research funded through this initiative continues to produce additional and important findings related to the impacts of smoke. One topic of vital interest to both the fire management community and the general public is the health impacts due to exposure from wildland fire smoke. This is increasingly important given the increasing rate of wildfire smoke exposure to communities. The following examples demonstrate that science can be a valuable long-term investment, providing the information needed by management to meet both current and future challenges.

Evaluating the Evidence and Filling the Gap

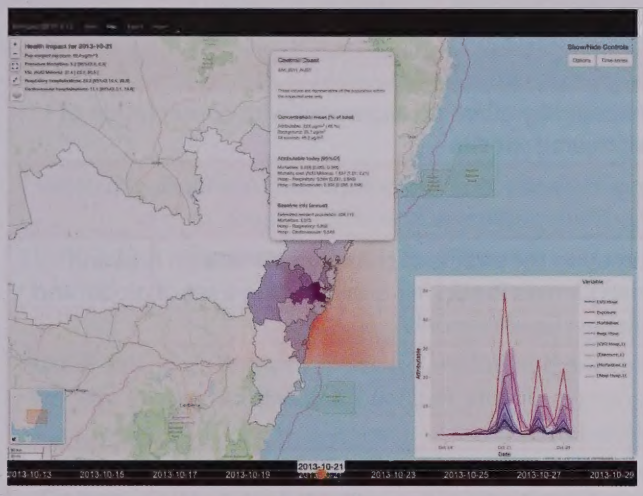
A past JSFP-funded study reviewed and synthesized the health effects of wildfire smoke exposure from 375 epidemiological and experimental studies (Adetona et al. 2016). The authors concluded that there is a strong association between acute smoke exposure and respiratory effects to the general public. However, this review exposed the lack of available research on occupational exposure by firefighters; there was not enough information to make any conclusions about health impacts.

To remedy this data gap, additional research directly measured smoke exposure (i.e., carbon monoxide, particulate matter, dust) to fire personnel over a 4-year time period across various fire types (e.g., initial attack), crew types (e.g., engine crew), incident activities (e.g., mop-up), and other variables (Navarro et al. 2019). This study provided baseline occupational exposure data and identified certain activities (e.g., mop-up) and fire types (e.g., prescribed fire) where occupational standards were exceeded. By identifying these important factors, fire managers might develop operation guidelines to reduce exposure among its workforce.

National Interagency Fire Center

Developing Tools for Predicting Health Impacts in Real Time

A separate, but related, JFSP-funded project by an international team of researchers resulted in development of a tool to estimate air quality and smoke-related health impacts from prescribed and wildland fire in real time (Reich et al. 2019). This tool linked statistical models with newly available data sources, modern health risk assessments, and health economic impacts (e.g., hospital visits, premature death, aggravated asthma). The goal was to develop a communication protocol for issuing a forecast to health officials in a format that can be easily interpreted and effectively used in the health mitigation decision process. A prototype forecasting tool is already available for Australia. The importance of further investment and development of these types of tools was shown during the recent 2019-20 bushfire season in Australia, in which more than 400 people died of smoke inhalation in eastern Australia alone and another 3,000 were hospitalized with respiratory and cardiac issues (Arriagada et al. 2020).



Screenshot of the tool used in Australia to estimate air quality and smoke-related health impacts from wildland fire (Reich et al. 2019).

"Smoke is just one of many problems that will intensify with the increasing frequency and severity of major bushfires associated with climate change."

–Arriagada et al. 2020

National Interagency Fire Center

Michelle Moore

Rick Lang

Smoke from 2020 bushfire in Australia.

Summary of 2018

Funded Research and Completed Projects

In 2018, the JFSP funded 9 Graduate Research Innovation projects out of 53 total proposals (17% of projects funded) (Table 1). Also in 2018, the JFSP received 33 final reports on research it funded (Table 2).

Ongoing research can be accessed at: https://www.firescience.gov/JFSP_research.cfm

Table 1. Number of FY 2018 research proposals received and funded by the JFSP.

Task Number	Research Topic	Proposals Received	Proposals Funded
18-1-01	Graduate Research Innovation (GRIN) Award	53	9

Table 2. Final reports funded by the JFSP that were completed in FY 2018.

Project ID	Principal Investigator	Project Title
12-1-06-46	Michael L. Morrison	Compatibility of fire management with conservation of endangered species
12-1-01-20	Jane E. Smith	Long-term effects of restoration fire and thinning on soil fungi, fine root biomass, and litter depth
13-1-01-4	Jeffrey R. Pierce	Estimating the effects of changing climate on fires and consequences for U.S. air quality, using a set of global and regional climate models
13-1-01-16	Uma X. Shankar	Assessing the impacts on smoke, fire and air quality due to changes in climate, fuel load, and wildfire activity over the Southeastern U.S.
13-1-03-7	Robert K. Grala	Benefits and costs of implementing fuel treatments on nonindustrial private forest (NIPF) lands in Mississippi
13-1-03-12	Matthew P. Thompson	Evaluating spatiotemporal tradeoffs under alternative fuel management and suppression policies: Measuring returns on investment
13-1-04-4	Jonathan D. Bakker	Monitoring effectiveness of forest restoration treatments: The importance of time and space
13-1-04-44	Cathryn H. Greenberg	Reptile, amphibian, breeding bird, and invertebrate response to prescribed fires and mechanical fuel reduction treatments in an upland hardwood forest
13-1-04-49	J. Morgan Varner III	Restoration synchrony of fuels and biodiversity in fire-excluded oak-hickory woodlands in north Mississippi
13-1-05-7	Penelope Morgan	Masticated fuels and fire behavior in forests of the Interior West
13-1-06-1	Kirk W. Davies	Restoring sage-grouse habitat after fire: Success of different restoration methods across an elevation gradient
14-1-01-23	Brandon M. Collins	Effects of fuels management on fire intensity, rate of spread, severity, and resultant forest structure within the 2013 Rim Fire landscape
14-1-02-21	Larissa L. Yocom	Wildfire effects on subsequent wildfire ignition, severity, and management in the Southwest: Applying massive data sets to address management questions

Project ID	Principal Investigator	Project Title
14-1-02-27	Andrew T. Hudak	How vegetation recovery and fuel conditions in past fires influences fuels and future fire management in five western U.S. ecosystems
14-1-05-7	Holly K. Ober	Managing with fire to promote the recently listed Florida Bonneted Bat, *Eumops floridanus*
14-1-06-11	Chuck C. Rhoades	The long-term legacy of the 2002 Hayman Fire on stream water quality and treatability
14-1-06-19	Alex T. Chow	Forest fire alters disinfection byproduct precursor exports from forested watersheds
14-1-06-22	Scott L. Stephens	Hydrology and fire in the Sierra Nevada: A possible win-win
14-2-01-29	Emily Jane Davis	Fire-adapted communities on the range: Alternative models of wildfire response
14-2-01-31	Patricia A. Champ	Is the whole greater than the sum of its parts? Homeowner wildfire risk mitigation, community heterogeneity, and fire adaptedness
14-5-01-1	Douglas B. Rideout	Programmatic analysis of fuel treatments: From the landscape to the national level
14-5-01-12	Armando X. González-Cabán	Do fuel treatment costs affect wildfire suppression costs and property damages? An analysis of costs, damages avoided and return on investment
14-5-01-25	Helen T. Naughton	Spatiotemporal evaluation of fuel treatment and previous wildfire effects on suppression costs
15-1-07-22	Andrew M. Barton	Pines vs. oaks revisited: Forest type conversion due to high-severity fire in Madrean woodlands
15-2-01-13 GRIN Project	Scott L. Stephens Student: Kristen L. Shive	Fire history and fire-climate interactions in high elevation whitebark pine dominated forests
15-2-01-14 GRIN Project	Alan H. Taylor Student: Catherine Airey Lauvaux	Fire history and fire-climate interactions in high elevation whitebark pine dominated forests
15-2-01-16 GRIN Project	Tamara Ticktin Student: Georgia Fredeluces	Influence of fire severity and canopy cover on the population dynamics and quality of beargrass
15-2-01-22 GRIN Project	Eva K. Strand Student: Chris M. Bowman-Prideaux	Do perennial bunchgrasses competitively exclude *Bromus tectorum* in post-fire rehabilitation across spatial scales?
15-2-01-34 GRIN Project	Andrew M. Latimer Student: Derek Young	Post-wildfire forest regeneration in a changing climate
15-2-01-57 GRIN Project	Stephanie K. Kampf Student: Codie R. Wilson	Precipitation thresholds for post-fire runoff, erosion and sediment delivery from hillslope to watershed scale
16-2-01-9 GRIN Project	Crystal A. Kolden Student: Aaron M. Sparks	Towards improved quantification and prediction of post-fire recovery in conifers
16-2-01-13 GRIN Project	Diana F. Tomback Student: Elizabeth R. Pansing	Effects of climate change and climate-altered fire regimes on whitebark pine populations
16-2-01-20 GRIN Project	Laura A. Burkle Student: Michael P. Simanonok	Native bee nesting habitat use after wildfire in Montana

Table 2 (continued). Final reports funded by the JFSP that were completed in FY 2018.

Summary of 2019

Funded Research and Completed Projects

In 2019, the JFSP funded 4 core research projects and 20 Graduate Research Innovation projects out of 52 total proposals (46% of projects funded) (Table 3). Also in 2019, the JFSP received 22 final reports on research it funded (Table 4).

Table 3. Number of FY 2019 research proposals received and funded by the JFSP, by research topic.

Task Number	Research Topic	Proposals Received	Proposals Funded
19-1-01	Graduate Research Innovation (GRIN) Award	38	20
19-2-01	Effectiveness of fuel breaks and fuel break systems	5	1
19-2-02	Reducing damages and losses to valued resources from wildfire	9	3
Total		**52**	**24**

Table 4. Final reports funded by the JFSP that were completed in FY 2019.

Project ID	Principal Investigator	Project Title
10-S-02-06	Loretta Singletary	Evaluate the effectiveness of the JFSP regional consortia
13-1-06-16	Steven E. Sesnie	Determining prescribed fire and fuel treatment compatibility with semidesert grassland habitat rehabilitation for the critically endangered masked bobwhite quail (*Colinus virginianus ridgwayi*)
14-1-01-2	Eva L. Loudermilk	Outcomes prioritization on fuel treatment placement in extreme fire weather in 3 CFLRP landscapes
14-1-01-4	John M. Kabrick	Effects of fuels treatments on reduction of fire risk and restoration of oak-pine forests in Central Hardwood Forest landscapes
14-1-01-7	Beth A. Newingham	Do post-fire fuel treatments and annual grasses interact to affect fire regimes in the Great Basin?
14-1-02-9	Andrew J. Larson	Influence of past wildfires on wildfire effects in northern Rockies mixed-conifer forest
14-1-02-30	Susan J. Prichard	Evaluation of past-fire mosaics on subsequent wildfire behavior, severity and management strategies
14-1-03-44	Kelley C. Barsanti	Synthesis of comprehensive emissions measurements and multi-scale modeling for understanding secondary organic aerosol chemistry in wildland smoke plumes
14-1-04-9	Brian J. Reich	Estimating fire smoke related health burden and novel tools to manage impacts on urban populations
14-1-04-16	Ian M. Gilmour	The role of composition and particle size on the toxicity of wildfire emissions
14-1-05-22	Luke E. Dodd	A long-term evaluation of the interacting effects of fire and white-nose syndrome on endangered bats
14-1-06-14	Terri S. Hogue	Post-fire water quality: An investigation of determinants and recovery processes in burned watersheds in the Western U.S.
14-1-06-18	Ge Sun	Wildfire and fuel treatment strategy effects on water quantity across the conterminous United States
14-5-01-27	Joseph M. Little	Duration and cost effectiveness of fuel treatments in the Alaska boreal region

Project ID	Principal Investigator	Project Title
15-1-03-20	Sean A. Parks	Quantifying the risk of fire-facilitated transition to non-forest in California and the Southwest
15-1-04-4	Aixi Zhou	Fire ember production from wildland and structural fuels
15-1-05-5	Leda N. Kobziar	The consequences of soil heating for prescribed fire use and fire restoration in the South
15-1-05-11	Peter R. Robichaud	The next generation soil heating model
15-1-07-19	Eric E. Knapp	Vegetation succession in an old-growth ponderosa pine forest following structural restoration with fire: Implications for retreatment and maintenance
15-1-07-39	Francis F. Kilkenny	Vegetation succession in post-fire seeding treatments
16-2-01-27 GRIN Project	Peter J. Weisberg Student: Alexandra K. Urza	Post-fire recruitment of Great Basin big sagebrush species: Spatial and temporal controls along regional gradients of soil temperature and moisture
17-2-01-25 GRIN Project	Joel N. Hartter Student: Angela E. Boag	Impacts of multi-year drought on post-fire conifer regeneration in the Inland Northwest

Table 4 (continued). Final reports funded by the JFSP that were completed in FY 2019.

Fire Science Exchange Network

Accomplishments

The JFSP supports a network of 15 fire science exchanges based on broad ecoregions across the entire U.S. The overarching goal of the exchange network is to facilitate the exchange of the most relevant and current wildland fire science information to federal, tribal, state, local, and private stakeholders within ecologically similar regions.

Face-to-Face Science Delivery in FY 2018 and 2019

- Nearly 14,000 participants
- About 500 field trips and consultations

Leadership Briefings: Informing Decisionmakers/Obtaining Feedback

- More than 300 leadership briefings
- Including about 8,150 decisionmakers

"The most important role of the exchanges is creating regional fire communities that connect a diverse range of fire professionals."

–Response to fire exchange internal survey

Improving Outreach through Review and Participant Feedback

Just like its parent program, the fire exchanges are focused on program improvement through periodic review of their activities and investments. Each of the exchanges gets feedback from participants in sponsored activities, while some also have an advisory board composed of important partners—such as universities, research stations, land management agencies (local, state, and federal), and local and state fire agencies. Feedback from participants, which is part of the exchange process, has been used for a number of purposes including: to identify knowledge gaps needed to improve resource management, to help tailor topics of interest for field trips and presentations, to identify the types of activities most valuable to exchange participants, and to improve the style/methods/presentations of activities such as workshops and conferences for more effective learning.

Joe Marschall

The Oak Woodlands and Forests Fire Consortium cohosted this tour with the Daniel Boone National Forest and the Forest Stewards Guild. The field tour focus was on prescribed fire treatments at shortleaf pine restoration sites. Attendees included managers and researchers from more than 12 agencies representing 5 states.

The feedback for many of the exchanges identified information-sharing field trips as one of the most valuable activities. These face-to-face events allow researchers, land managers, the public, and private industry opportunities to learn about the latest research, to network and hear perspectives from partners, and to provide opportunities for collaboration. These types of events, although more effective for science exchange and delivery, take more time to implement. Nevertheless, the exchanges have continued to host more than 1,000 activities/events per year over the past 5 years (Figure 3).

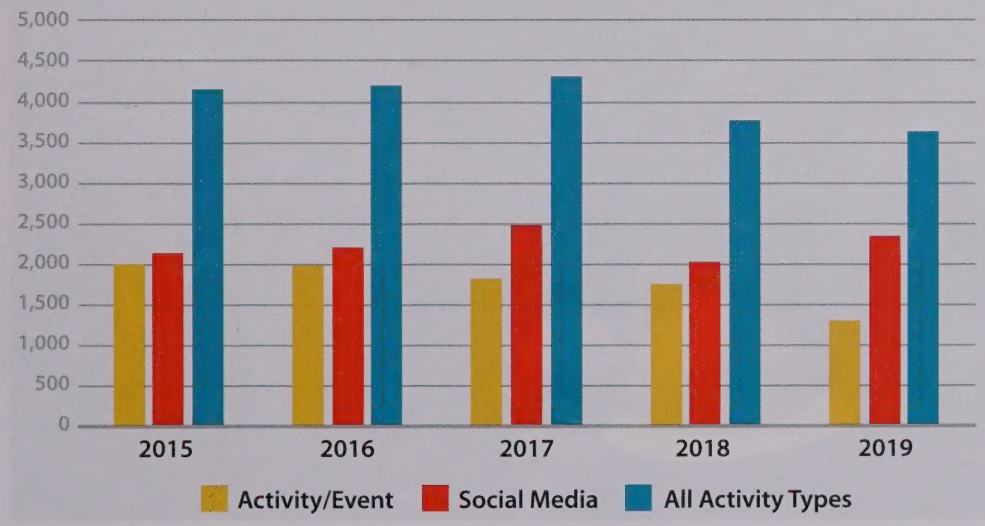


Figure 3. Number of Fire Science Exchange Network activities from FY 2015 through FY 2019.

What Others Are Saying About FSEN

"This group is very valuable to the fire agencies. Application of the science is always a challenge, but we are making progress. It is great that we have the consortium available to us!"

–Anonymous post-event comment to the Alaska Fire Science Consortium

"It's great to see the superb cooperation and coordination of several government agencies and private organizations in pursuit of a common goal. Well done!"

–Anonymous post-event comment to the Oak Woodlands and Forests Fire Consortium

"The information was real world applicable."

–Anonymous post-event comment to the Pacific Fire Exchange

"The Joint Fire Science Exchange Network continues to help fire managers make progress on utilizing the best available science. An example of this support is the work several Exchanges are providing in the NFDRS 2016 Rollout. This rollout seeks to inform fire managers of the new NFDRS model along with enhanced best practices on developing and implementing Interagency Fire Danger Operating Plans."

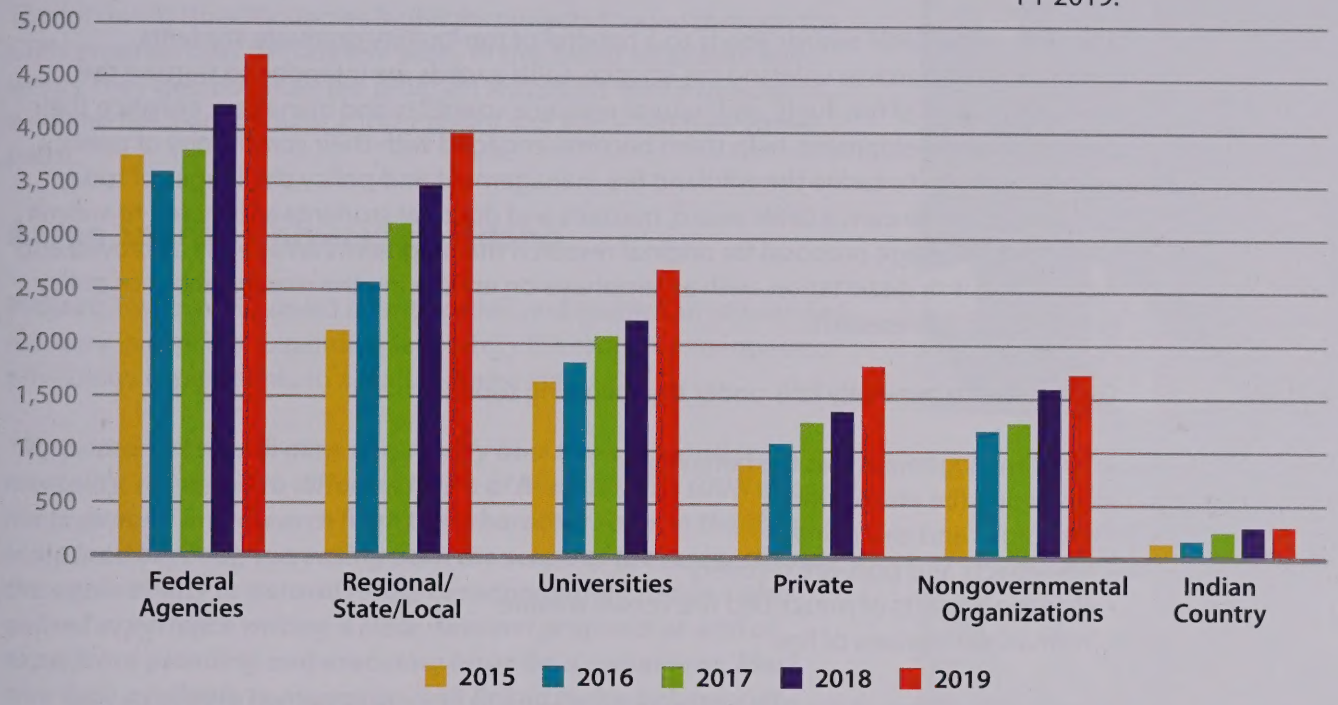
–Clint Cross, U.S. Forest Service Assistant Director, Landscapes and Partnerships, Fire and Aviation

The Northwest Fire Science Consortium cohosted this field tour. Discussion centered on the aftermath and fire recovery plan of the 36 Pit Fire in Oregon, as well as fuel hazard reduction practices and the use of strategically located fuel breaks. Attendees included managers/line officers from several state and federal agencies, community members, scientists, and landowners.

Carrie Berger

Figure 4 shows a year-to-year comparison of the number of exchange network participants by organizational group. Federal agency participation, which was already high, increased by 25% over the past 5 years. Due to a concerted effort by the fire exchanges, other stakeholder groups increased substantially, including an 86% increase in regional/state/local government and a 103% increase in tribal nation participation. The 2017 program review encouraged the JFSP to increase participation in these categories.

Figure 4. Number of Fire Science Exchange Network participants by organizational group (year-to-year comparison) from FY 2015 through FY 2019.



David Godwin, Southern Fire Exchange

Members of the Fire Science Exchange Network in Berkeley, California, for their annual meeting in 2018. The group meets annually to learn new methods of science delivery, technology, and options to collaborate.

Graduate Research INnovation (GRIN):

JFSP's Contribution to the Next Generation of Wildland Fire Managers and Scientists

The JFSP offers GRIN awards yearly to a handful of top-quality graduate students conducting research in wildland fire science. GRIN awards are intended to nurture the next generation of fire, fuels, and natural resource scientists and managers, enhance their professional development, help them become engaged with their community of peers, and equip them to tackle the wildland fire management and policy challenges of today and tomorrow. To earn a GRIN award, master's and doctoral students are invited to submit a succinct five-page proposal for original research that augments an already approved and funded thesis or dissertation, with an emphasis on enhancing the management or policy relevance of the research.

GRIN research generally falls under the following topics:

- Fuels management and fire behavior
- Changing fire environment
- Emissions and air quality
- Fire effects and post-fire recovery
- Relative impacts of prescribed fire versus wildfire
- Human dimensions of fire

From the inception of the GRIN program in fiscal year 2011 through 2019, 79 graduate students have received GRIN awards up to $25,000 each, a total investment of almost $1.9 million (Figure 5). A key partner over these 9 years has been the Association for Fire Ecology, which has organized and executed the external peer review component of the selection process through its Education Committee. The application process provides students experiences of putting proposals together, receiving professional feedback, and participating in the peer review process. Overall, the GRIN program enhances exposure of students to wildland fire management programs and policies; GRIN recipients are the managers, scientists, and leaders of tomorrow.

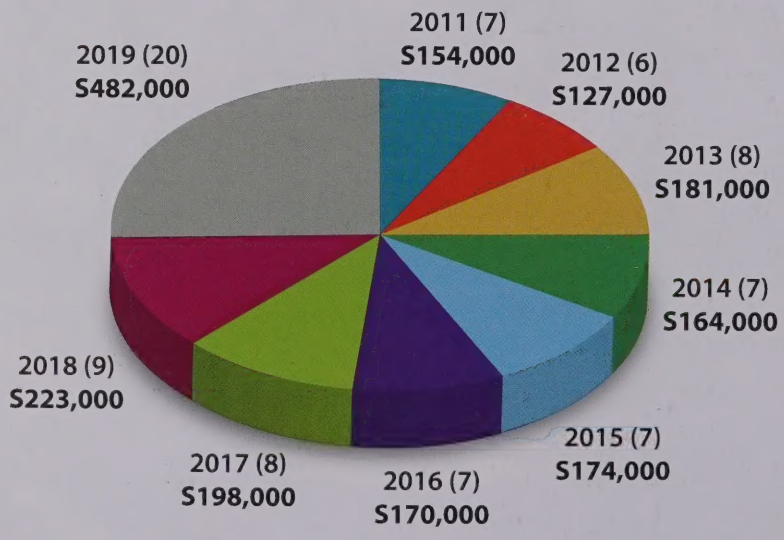


Figure 5. Funding of the Graduate Research Innovation (GRIN) program by fiscal year from FY 2011 through FY 2019. The number of JFSP-funded projects are in parentheses.

In Their Own Words:

GRIN's Direct Impacts on Wildland Fire Research and Career Paths

The following three examples highlight projects funded through the GRIN program over the last few years. In the award recipients' own words, they describe how the program enhanced their exposure to wildland fire management and/or policy and impacted their career paths.

Aaron Sparks, University of Idaho

Project: Towards improved quantification and prediction of post-fire recovery in conifers: Expanding laboratory fire radiative energy-tree physiology experiments to a mature forest stand

"My primary research aims to quantify how trees respond (e.g., mortality, recovery) to different levels of fire intensity. GRIN allowed me to expand my research from the laboratory scale to the stand scale (and beyond), increasing both the scope of the research and the applicability to natural resource management needs. I also gained experience writing a clear, succinct proposal as well as experience planning and executing large field campaigns. Most tree data available to managers isn't linked to fire behavior at appropriate scales. We hope that the laboratory data and mature tree growth and recovery data we collected on our stand scale prescribed fires will contribute to more informed planning and policy decisions."

Career impact: "The research we are doing here at UI (University of Idaho) represents a substantial divergence from the established fire severity research and, at the start, was potentially a riskier funding opportunity—as we did not know what we would find. Through this GRIN, and other sources, we were able to provide further evidence that this is a worthwhile line of research, not only for answering scientific questions but also for improving resource management decisions. This research has led to a plethora of new questions regarding tree responses to fire and has allowed me to explore and disseminate more information than originally proposed. I will undoubtedly build off this groundwork of research as I move forward in my wildland fire career."

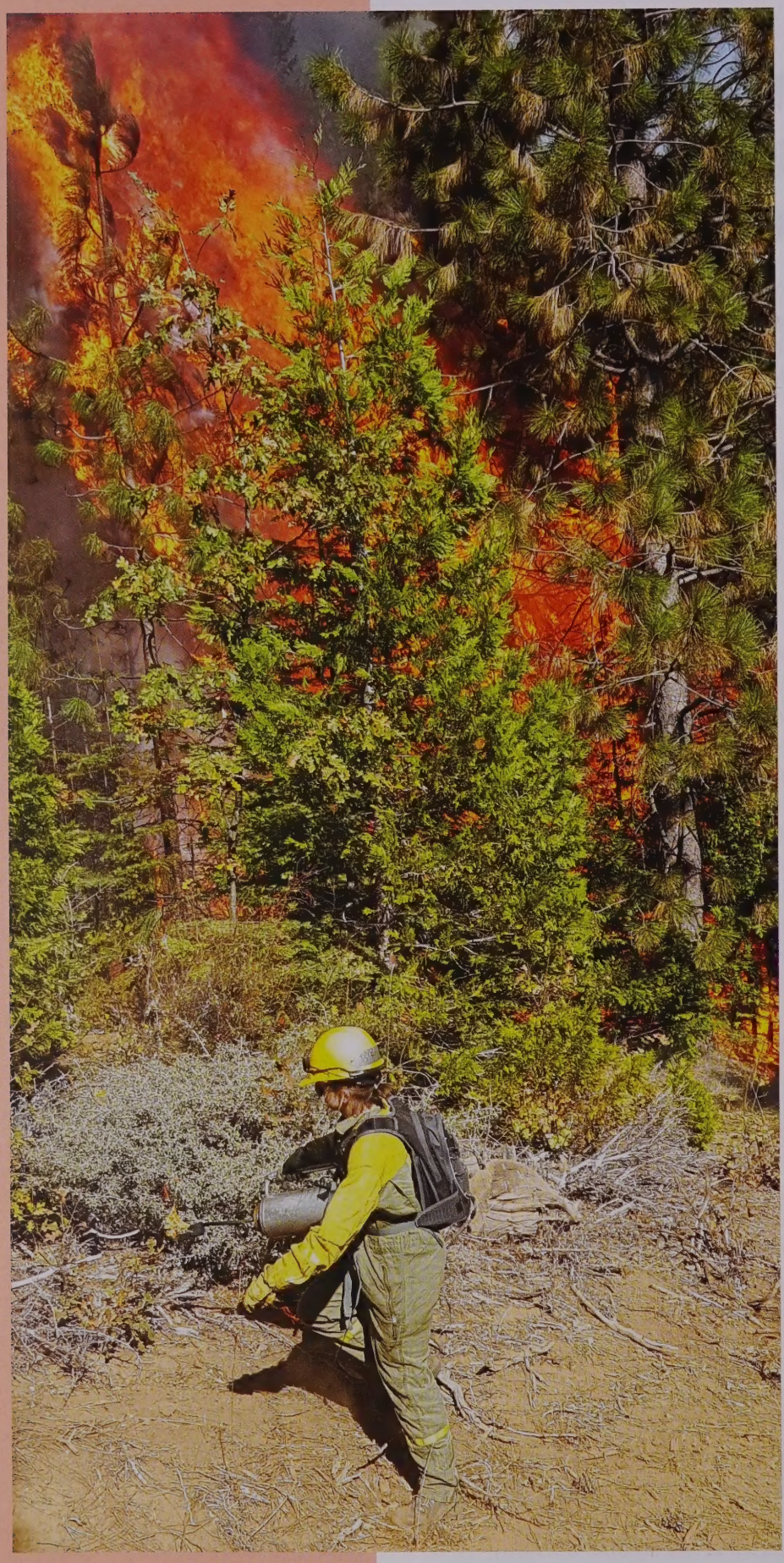
Next steps: Aaron is currently a postdoctoral researcher at the University of Idaho. He is working to develop a fire analysis portal for the Global Wildfire Information System, an internet-based repository of global fire information. This portal uses satellite observations of fires (from 2001 to present day) and provides users with global burned area maps, summary charts, and downloadable data that can be understood and used by land managers and policymakers.

Alistair Smith, University of Idaho

At the University of Idaho, Aaron Sparks, GRIN award recipient, collects spectral reflectance of sapling foliage that was subjected to surface fires of known intensity.

Aaron Sparks

Prescribed fire experiments in ponderosa pine stands at the University of Idaho Experimental Forest. Fire intensity was quantified via tower-mounted dual-band infrared radiometers (photo center) and linked to post-fire tree growth and physiology data.



Rick Satomi

Carmen Tubbesing, GRIN award recipient, assists with a prescribed burn at Blodgett Forest.

Carmen Tubbesing, University of California, Berkeley

Project: Predicting forest recovery following high-severity fire

"My GRIN award has enabled me to conduct an additional season of field work on understory competition following fire, including in areas that experienced mastication and prescribed fire. During this field season, I worked and lived at Blodgett Forest Research Station, an actively managed forest owned by UC Berkeley's Center for Forestry. I assisted with preparing areas for mastication and served as an igniter during a prescribed burn. Through this experience, I gained exposure to the challenges faced in implementing real-world fuels reduction treatments, which helped me think through applied research questions that may be useful to managers."

Career impact: "I am passionate about both fire management and data science. In my career, I hope to increase data science best practices, such as reproducibility, collaboration, and statistical rigor, in the world of fire research and management. The GRIN has enabled me to keep one foot solidly in each of the two worlds I care about; with the additional research support, I have been able to continue training as a data scientist while also performing field and lab work."

Next steps: Carmen is currently working on her PhD at UC Berkeley. Her dissertation research addresses two overarching questions: (1) how proactive management might increase forest resilience to moderate fire behavior and improve recovery; and (2) how forests grow back from high-severity fire without management intervention.

Nickolas Kichas, Montana State University

Project: Evaluating whitebark pine (*Pinus albicaulis*) resistance and resilience to fire and insect outbreaks in northwestern Montana

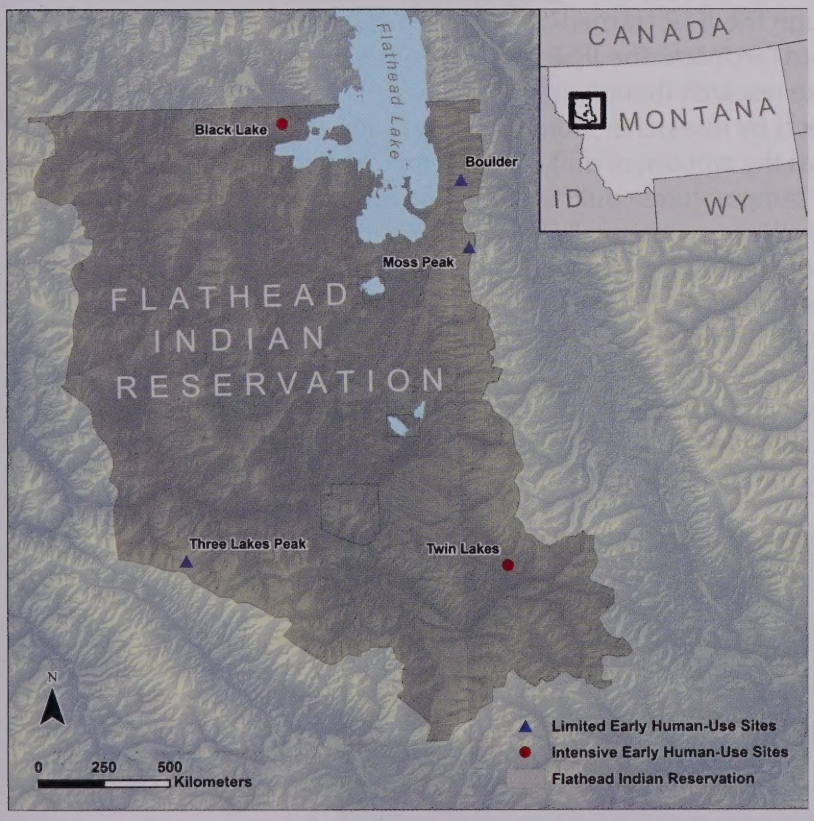
"Funding from this project has enabled me to collect data at a new whitebark pine study site that would otherwise not have been possible. I had wanted to engage in a more detailed assessment of the impacts of fire on whitebark pine physiology, and the GRIN program provided a fantastic opportunity to conceptualize and refine methods relating to this investigation. The acceptance of my GRIN proposal prompted me to transition from a master's to a PhD program at Montana State University, and I am eager to engage in this research over the next 2 years. I am exceedingly grateful for this incredible opportunity, and I hope to provide results that may inform management of whitebark pine for the Confederated Salish and Kootenai Tribes and the larger scientific community."

Career impact: "This project has great potential for me to establish important connections within the fire management community and may help inform the Tribal Forestry program of the Confederated Salish and Kootenai Tribes (CSKT) by contributing knowledge of whitebark pine growth and defense characteristics in relation to disturbance. Through this opportunity, I will coordinate with CSKT Tribal Forestry as well as researchers at the USFS Missoula Fire Sciences Laboratory and through the JFSP Northern Rockies Fire Science Network. I look forward to working with these groups over the course of this project."

Next steps: Nickolas is working on his PhD at Montana State University, examining the physiological response of whitebark pine to fire in high-, mixed-, and low-severity fire regimes.

"I would not have opted to pursue a PhD degree were it not for the GRIN funding and support of my proposal. This program has provided me an opportunity to expand my professional network."

–Nickolas Kichas,
GRIN awardee,
Montana State University



Whitebark pine study area on the Flathead Indian Reservation in Montana. Map courtesy of Nickolas Kichas.

Whitebark pine.

Dealing with Duff:

Improving Prescribed Fire Success in the Southeast through the Joint Fire Exchange Process

Pineland communities in the southeastern coastal plain serve as important habitat for red-cockaded woodpeckers and other wildlife, while also having substantial timber value. These communities are highly dependent on fire to maintain species diversity and structural composition. However, much of this community type has gone years without fire, and early efforts to reintroduce fire often led to undesirable tree mortality—in some cases, more than 90% of large trees. Although land managers recognized that frequent fires are necessary for the health of pine communities, the risk of tree death was a considerable obstacle to reintroducing fires into older stands. Some believed that thick layers of duff (partially decomposed leaves, needles, and other plant material), which can buildup due to fire exclusion, played a role, but a lack of information on the underlying mechanisms of tree mortality stymied development of operational solutions.

J.M. Varner

Duff burning around a tree bole.

Research Identified and Driven by Fire Management Needs

The Southern Fire Exchange, one of 15 science exchanges nationwide that is funded through the JFSP, learned of this issue from land manager surveys and advisory board feedback. The JFSP recognized the importance of this issue and helped initiate research though grant funding opportunities. One of the first funded projects by researcher Morgan Varner found that a strong predictor of tree death was the amount of duff consumed in smoldering fires (Varner et al. 2005). Lethal temperatures could be sustained for well over an hour in the duff and mineral soil layers, potentially killing feeder roots that had grown there in the absence of fire. Subsequent work discovered that duff consumption and hence tree mortality was related to duff moisture (Varner et al. 2007). Stands that burned with lower duff moisture also experienced greater tree mortality, especially trees in the largest size classes. The physiological mechanism for duff fire-caused mortality was also investigated (Varner et al. 2009). Longer smoldering times were linked to larger reductions in coarse root carbohydrate storage, likely removing resources for tree recovery after fire.

David Godwin, Southern Fire Exchange

An infrared thermal camera is used to monitor surface fire behavior during a prescribed fire in north-central Florida.

J. Kreye, Eglin Air Force Base

Infrared thermal image of a prescribed fire. Heavy duff fuel loads lead to long duration ground fires with lethal temperatures.

Shifting Fire Management Strategies

Taken together, these new findings suggest an appropriate course of action would involve gradually removing deep duff and slowly favoring decomposition without destroying the tree's feeder roots. This could be achieved by burning under moderate conditions when duff is sufficiently moist, such as after several days of light rain and under nondrought conditions. This alternative approach was a game changer for management strategies that had previously focused on getting an intense fire into timber stands to quickly clear out the dense midstory of shrubs. "It changed the focus to fuels first and ecosystem structure later," said Kevin Hiers, a fire scientist at Tall Timbers Research Station. "[In addition,] this work identified how little we knew about fire-caused stress and mortality," Varner pointed out. "This research was one of the first projects to identify duff consumption as a major driver in tree mortality models. It spawned several papers on mortality, stress, and pushed reviews of the topic forward."

David Godwin, Southern Fire Exchange

Regional land managers attend a workshop and field tour addressing pineland restoration issues, including duff fire-caused mortality. Attendees learn how to measure duff moisture and discuss the conditions best suited for prescribed fire restoration treatments.

Delivering Science to Improve Land Management

The researchers and the Southern Fire Exchange recognized the need to move duff fire research findings into the hands of regional land managers. Working together, they have shared findings and provided training opportunities at workshops, field tours, prescribed fire council meetings, and conferences across the South. At these events, the research group discussed formulating burn prescriptions based on rainfall and drought index conditions, assessing duff moisture with moisture meters or a simple "touch test," and site preparation techniques such as removing coarse fuels and lightly raking the duff in some instances. "We checked every box from grassroots, manager-to-manager outreach to publishing in the peer-reviewed literature," said Varner. The funded research and resulting training opportunities through the Fire Science Exchange Network promoted solutions and served to increase awareness of duff science.

The most exciting outcome of this science exchange process is how land managers have incorporated research findings into their prescribed fire operating procedures. Brett Williams, fire manager at Eglin Air Force Base, noted that managers are now more likely to consider duff issues when writing management prescriptions and to actively evaluate weather and fuel conditions (specifically of duff) prior to a fire. Ivor Kincaide, the land stewardship director for Alachua Conservation Trust in Florida, affirmed this change in management strategy. "The challenges that duff fires present are the perfect example of the benefit of connecting academic research to land managers," said Kincaide. "Duff fires used to be pretty routine on our burns. Today, we follow 'days since rain' as well as the amount of rain on our burn units much more carefully. We don't have expensive moisture meters or other new equipment, but we have good 'rules of thumb' based on real quantitative science, and that makes a big difference."

"The challenges that duff fires present are the perfect example of the benefit of connecting academic research to land managers."

–Ivor Kincaide,
Alachua Conservation Trust

A fact sheet and educational videos created by the Southern Fire Exchange to expand outreach to land managers and others who were unable to attend duff fire workshops and other events. For more information, visit southernfireexchange.org.


SOUTHERN Fire Exchange

SFE Fact Sheet 2018-4

Reintroducing Fire Into Long-Unburned Pine Stands: The Duff Problem

Austin K. Dixon, Kevin M. Robertson

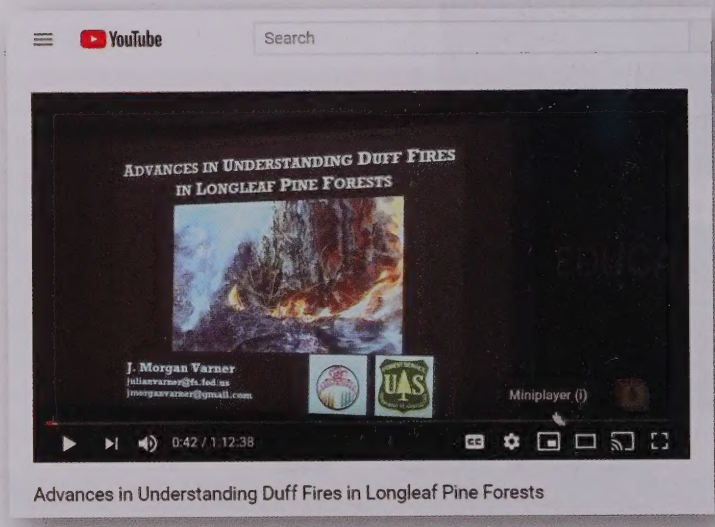
INTRODUCTION

What is Duff?

DUFF ACCUMULATION

DUFF COMBUSTION

Oi Litter
Oe Fermentation
Oa Humus
Mineral Soil



Advances in Understanding Duff Fires in Longleaf Pine Forests

Using a Duff Moisture Meter to Save Trees - Are...

Fire Management Lessons Learned when Burning Duff

Advances in Understanding Duff Fires in Longleaf Pine...

Joint Fire Science Program

Governing Board

The JFSP is jointly funded by the Departments of Agriculture and the Interior, and governence is through a 12-member Governing Board with 6 members from the U.S. Forest Service and 1 member each from the Bureau of Indian Affairs, Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, and Office of Wildland Fire. The current board members as of 2020 are:

Calvin Farris
National Park Service

Scott Goodrick
U.S. Forest Service

Bil Grauel
Bureau of Indian Affairs

Jolie Pollet
Bureau of Land Management

Craig Leff
Office of Wildland Fire

Mark Lichtenstein
U.S. Forest Service

Jim Menakis
U.S. Forest Service

Toral Patel-Weynand
U.S. Forest Service

Carl Petrick
U.S. Forest Service

Lisa Saperstein
U.S. Fish and Wildlife

Dana Skelly, Chair
U.S. Forest Service

Paul Steblein, Vice Chair
U.S. Geological Survey

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References

Adetona, O., T.E. Reinhardt, J. Domitrovich, G. Broyles, A.M. Adetona, M.T. Kleinman, R.D. Ottmar, and L.P. Noeher. 2016. Review of the health effects of wildland fire smoke on wildland firefighters and the public. Inhalation Toxicology 28: 95-139.

Arriagada, N.B., A.J. Palmer, D.M.J.S. Bowman, G.G. Morgan, B.B. Jalaludin, and F.H. Johnston. 2020. Unprecedented smoke-related health burden associated with the 2019-20 bushfires in eastern Australia. Medical Journal of Australia.

Davis, E.J., J. Abrams, and K. Wollstein. 2020. Rangeland Fire Protection Associations as disaster response organisations. Disasters 44 (3): 435-454.

Jolly, W.M., P.H. Freeborn, W.G. Page, and B.W. Butler. 2019. Severe fire danger index: A forecastable metric to inform firefighter and community wildfire risk management. Fire 2 (3): 47.

Navarro, K., M. Kleinman, C. Mackay, T. Reinhardt, J. Balmes, G. Broyles, R. Ottmar, L. Naher, and J. Domitrovich. 2019. Wildland firefighter smoke exposure and risk of lung cancer and cardiovascular disease mortality. Environmental Research 173: 462-468.

Page, W.G., and B.W. Butler. 2017. An empirically based approach to defining wildland firefighter safety and survival zone separation distances. International Journal of Wildland Fire 26: 655-667.

Reich, B., A. Rappold, F. Johnston, G. Morgan, N. Fann, M. Cope, and R. Broome. 2019. Estimating fire smoke related health burden and novel tools to manage impacts on urban populations. Final report to the Joint Fire Science Program, Project 14-1-04-9.

Varner, J.M., D.R. Gordon, F.E. Putz, and J.K. Hiers. 2005. Restoring fire to long-unburned *Pinus palustris* ecosystems: Novel fire effects and consequences for long-unburned ecosystems. Restoration ecology 13: 536-544.

Varner, J.M., J.K. Hiers, R.D. Ottmar, D.R. Gordon, F.E. Putz, and D.D. Wade. 2007. Overstory tree mortality resulting from reintroducing fire to long-unburned pine forests: The importance of duff moisture. Canadian Journal of Forest Research 37: 1349-1358.

Varner, J.M., F.E. Putz, J.J. O'Brien, J.K. Hiers, R.J. Mitchell, and D.R. Gordon. 2009. Post-fire tree stress and growth following smoldering duff fires. Forest Ecology and Management 258: 2467-2474.

Learn more about the JFSP at:

www.firescience.gov

National Interagency Fire Center
3833 S. Development Ave.
Boise, ID 83075-5354

Ed Brunson
Program Manager
(208) 387-5975

Karen Dante-Wood
Technology Transfer Specialist
(208) 387-5865

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